US009301268B2

(12) United States Patent
Reunamaki et al.

(10) Patent No.: US 9,301,268 B2
(45) Date of Patent: Mar. 29, 2016

(54) **DEVICE SYNCHRONIZATION**

(71) Applicant: **Nokia Technologies Oy**, Espoo (FI)

(72) Inventors: **Jukka Pekka Reunamaki**, Tampere (FI); **Arto Tapio Palin**, Viiala (FI); **Matti Sakari Hämäläinen**, Lempäälä (FI); **Niko Tapani Kiukkonen**, Veikkola (FI); **Janne Marin**, Espoo (FI)

(73) Assignee: **Nokia Technologies Oy**, Espoo (FI)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 84 days.

(21) Appl. No.: **14/076,123**

(22) Filed: **Nov. 8, 2013**

(65) **Prior Publication Data**

US 2015/0131645 A1 May 14, 2015

(51) **Int. Cl.**

H04L 1/00 (2006.01)
H04W 56/00 (2009.01)
H04W 4/00 (2009.01)

(52) **U.S. Cl.**

CPC ***H04W 56/00*** (2013.01); ***H04W 4/008*** (2013.01)

(58) **Field of Classification Search**

CPC H04J 3/0638; H04J 3/0639; H04J 3/064; H04J 3/0641; H04J 3/0642; H04W 56/00; H04W 56/01; H04W 56/02; H04W 56/03
USPC 370/350, 503
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,675,943	B2	3/2010	Mosig	
2009/0225172	A1	9/2009	Tsuchiya	
2012/0300944	A1 *	11/2012	Spittle	381/17

FOREIGN PATENT DOCUMENTS

CN	201388232	Y	1/2010

OTHER PUBLICATIONS

Pertila et al., "Closed-Form Self-Localization of Asynchronous Microphone Arrays", Joint Workshop on Hands-free Speech Communication and Microphone Arrays, May 30-Jun. 1, 2011, 6 pages.
Sachar et al., "Microphone Position and Gain Calibration for a Large-Aperture Microphone Array", IEEE Transactions on Speech and Audio Processing, vol. 13, Issue 1, Jan. 2005, pp. 42-52.

* cited by examiner

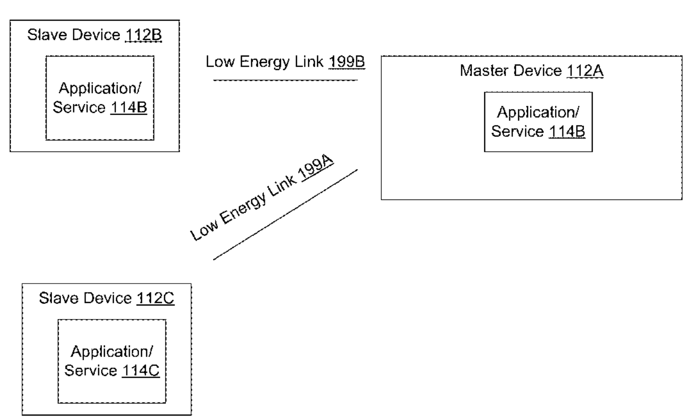
Primary Examiner — Dady Chery
(74) *Attorney, Agent, or Firm* — Mintz Levin Cohn Ferris Glovsky and Popeo, P.C.

(57) **ABSTRACT**

Methods and apparatus, including computer program products, are provided for device synchronization. In one aspect there is provided a method. The method may include establishing, at a first wireless device, a clock to be shared with at least a second wireless device; and sending, by the first wireless device over a short-range wireless link, a command to at least the second wireless device, the command indicating an operation to be performed by at least the second wireless device at a time defined by the clock. Related apparatus, systems, methods, and articles are also described.

15 Claims, 10 Drawing Sheets

100



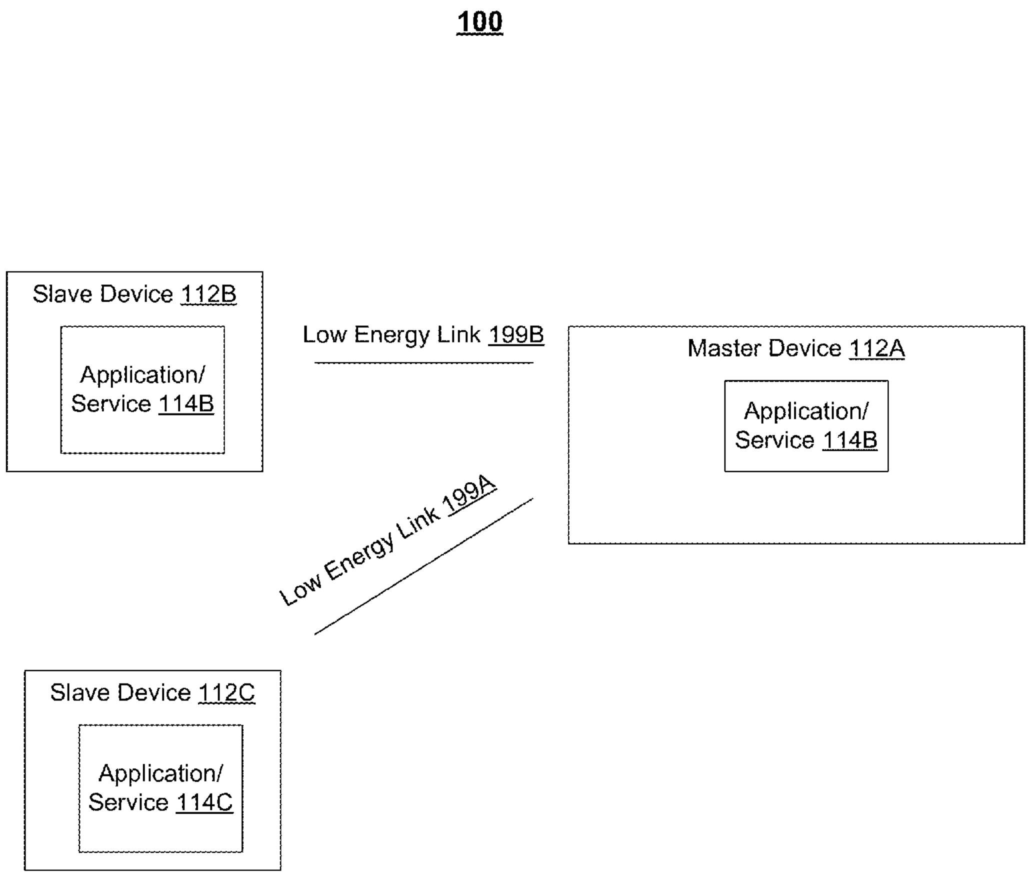

100
Slave Device 112B
Application/ Service 114B
Low Energy Link 199B
Master Device 112A
Application/ Service 114B
Low Energy Link 199A
Slave Device 112C
Application/ Service 114C

FIG. 1

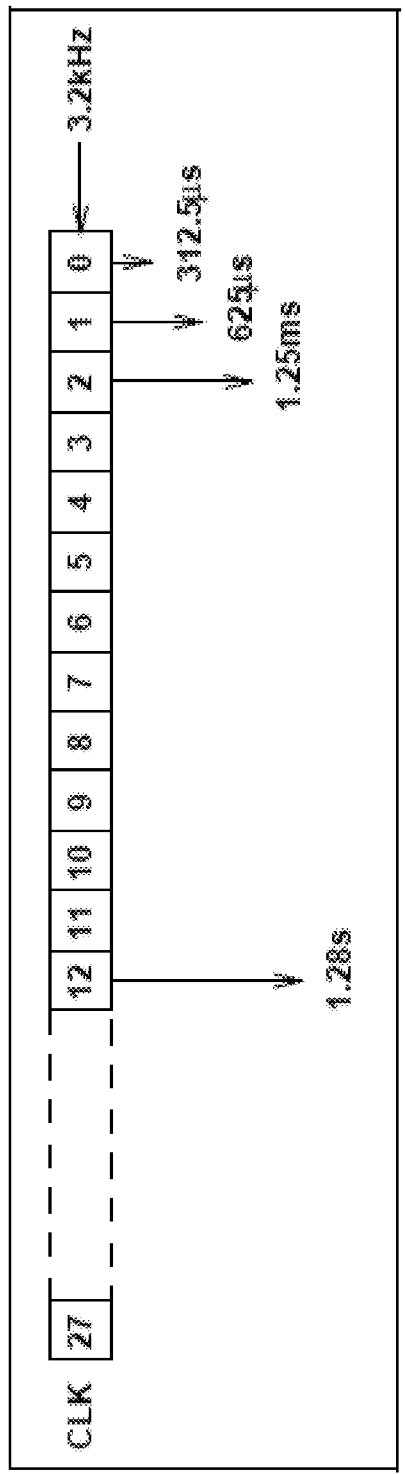


FIG. 2

300

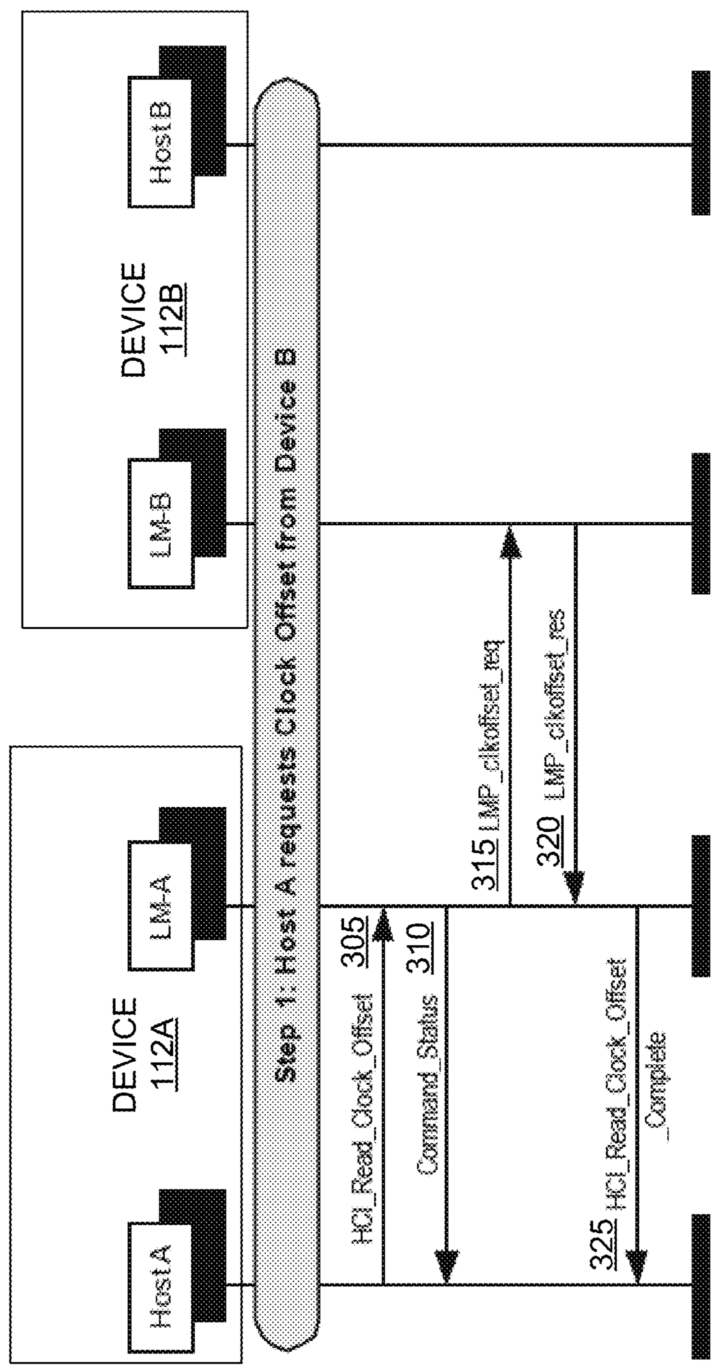

DEVICE 112A
Host A
LM-A
DEVICE 112B
LM-B
Host B
Step 1: Host A requests Clock Offset from Device B
305 HCI_Read_Clock_Offset
310 Command_Status
315 LMP_clkoffset_req
320 LMP_clkoffset_res
325 HCI_Read_Clock_Offset _Complete

FIG. 3

400

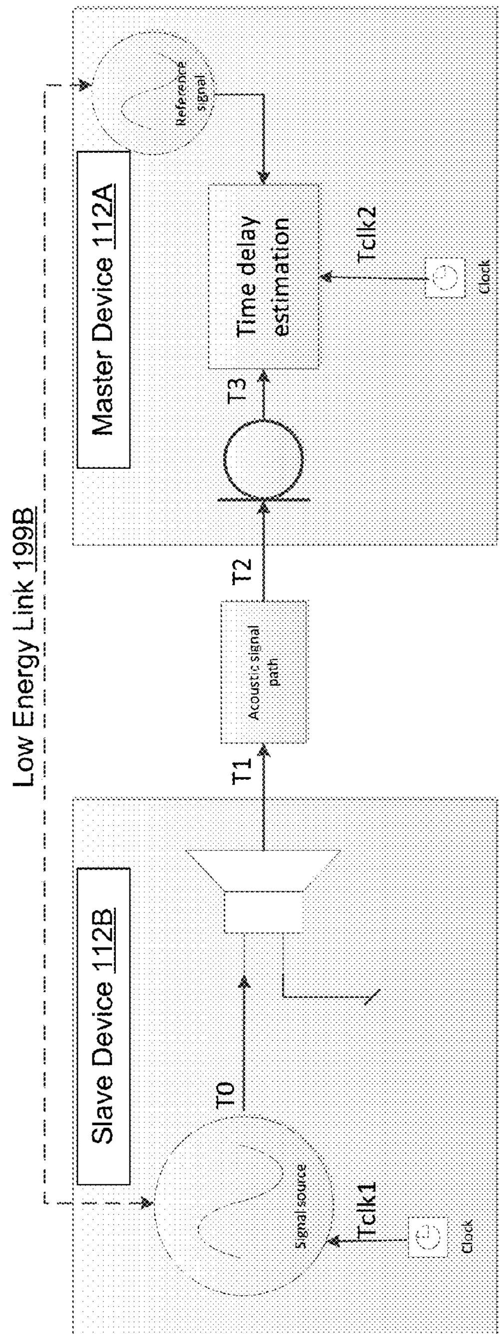

Low Energy Link 199B
Master Device 112A
Reference signal
Time delay estimation
Tclk2
Clock
T3
T2
Acoustic signal path
T1
Slave Device 112B
T0
Signal source
Tclk1
Clock

FIG. 4

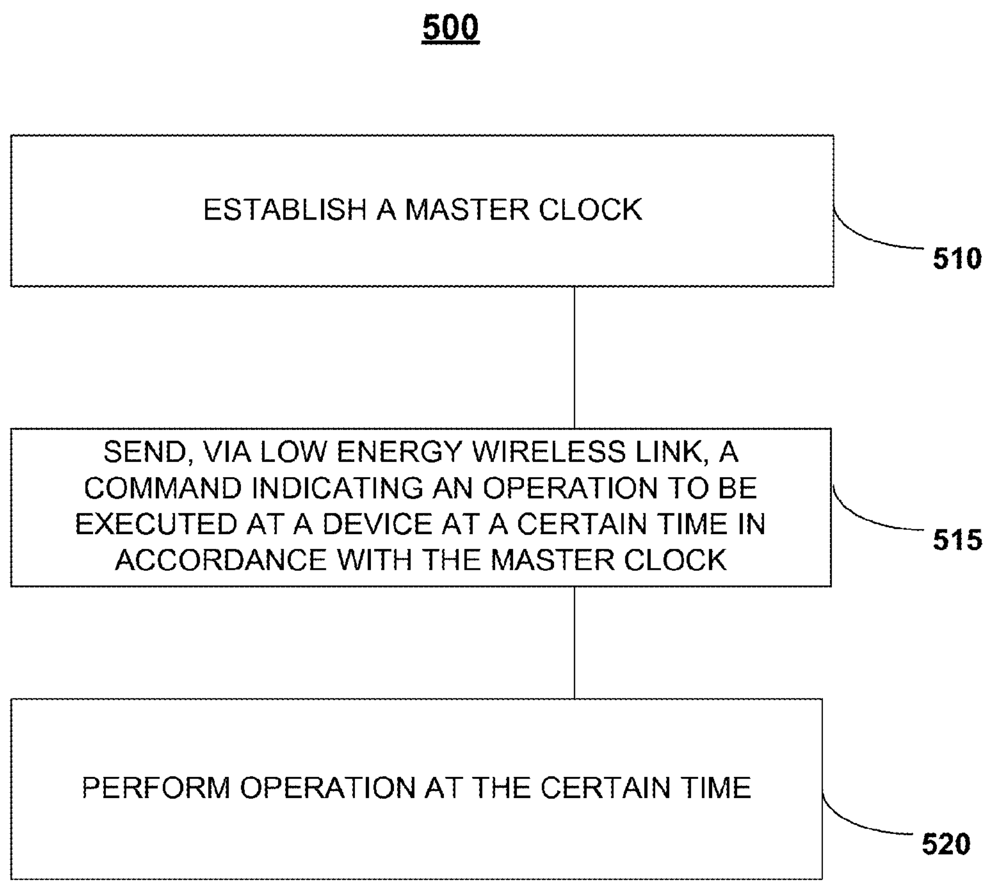

500
ESTABLISH A MASTER CLOCK
510
SEND, VIA LOW ENERGY WIRELESS LINK, A COMMAND INDICATING AN OPERATION TO BE EXECUTED AT A DEVICE AT A CERTAIN TIME IN ACCORDANCE WITH THE MASTER CLOCK
515
PERFORM OPERATION AT THE CERTAIN TIME
520

FIG. 5

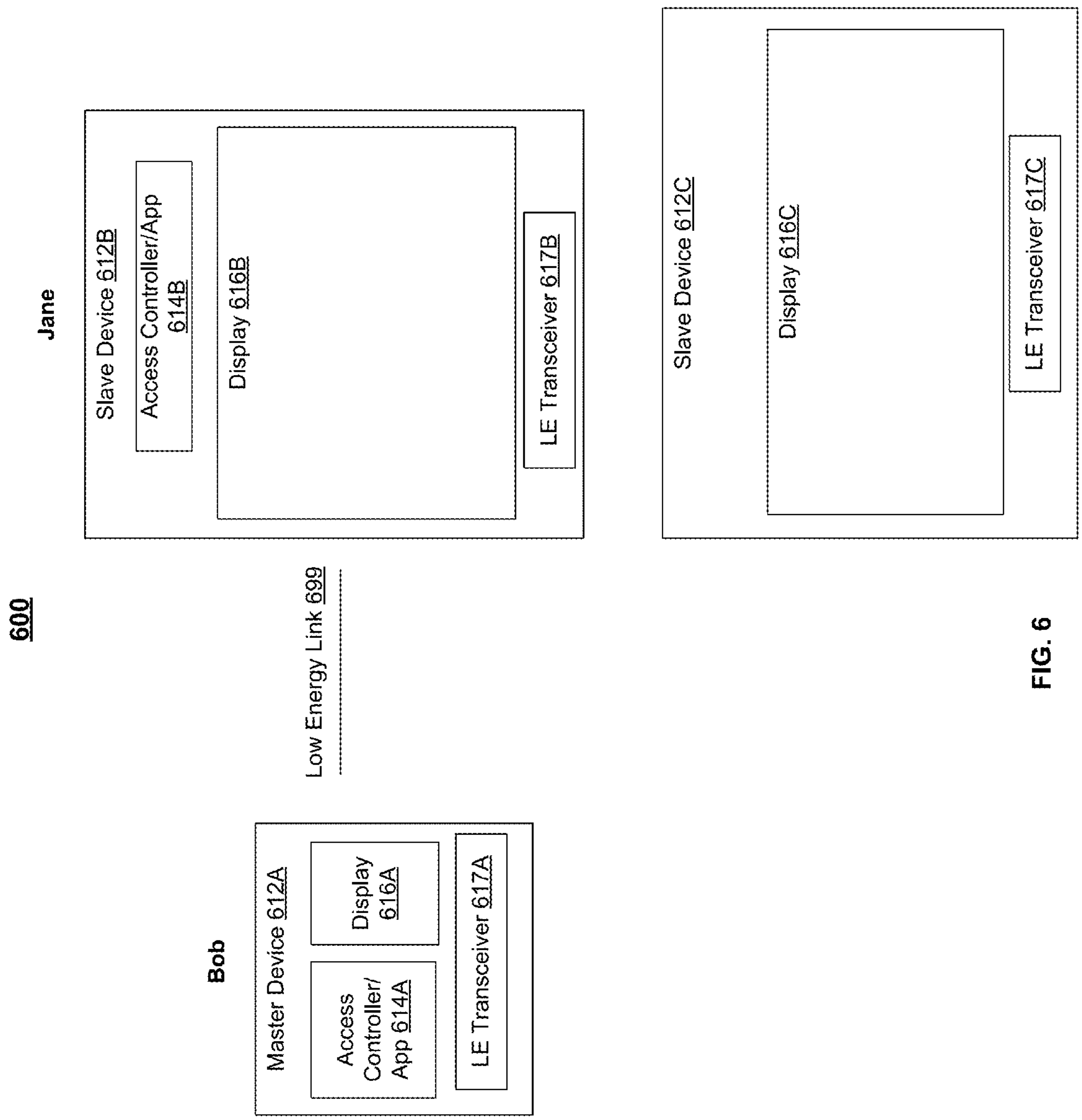

600
Jane
Slave Device 612B
Access Controller/App 614B
Display 616B
LE Transceiver 617B
Low Energy Link 699
Bob
Master Device 612A
Access Controller/ App 614A
Display 616A
LE Transceiver 617A
Slave Device 612C
Display 616C
LE Transceiver 617C

FIG. 6

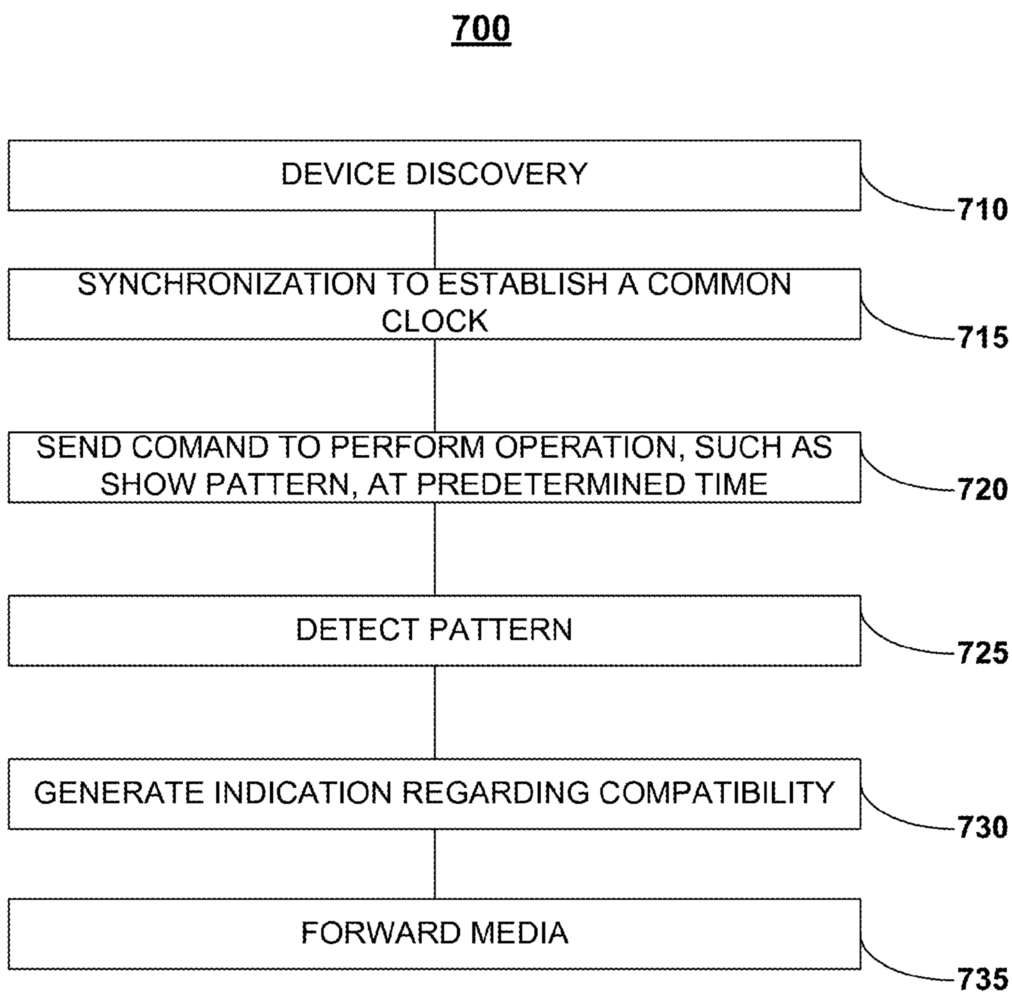

700
DEVICE DISCOVERY
710
SYNCHRONIZATION TO ESTABLISH A COMMON CLOCK
715
SEND COMAND TO PERFORM OPERATION, SUCH AS SHOW PATTERN, AT PREDETERMINED TIME
720
DETECT PATTERN
725
GENERATE INDICATION REGARDING COMPATIBILITY
730
FORWARD MEDIA
735

FIG. 7

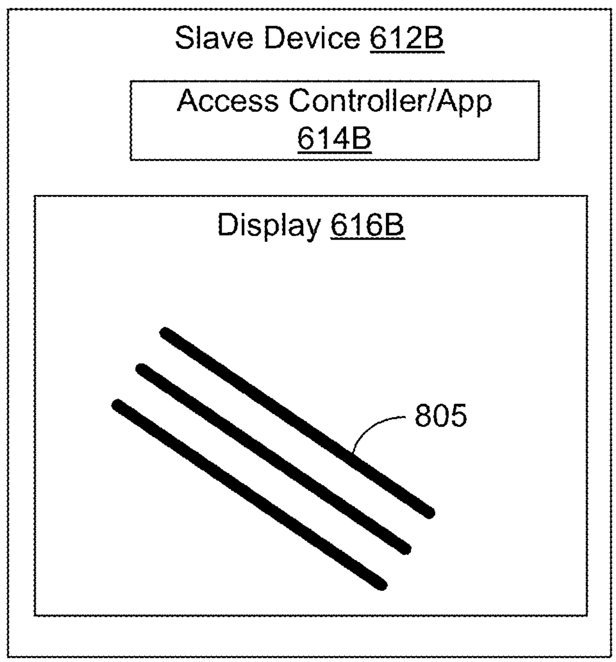

Slave Device 612B
Access Controller/App 614B
Display 616B
805

FIG. 8A

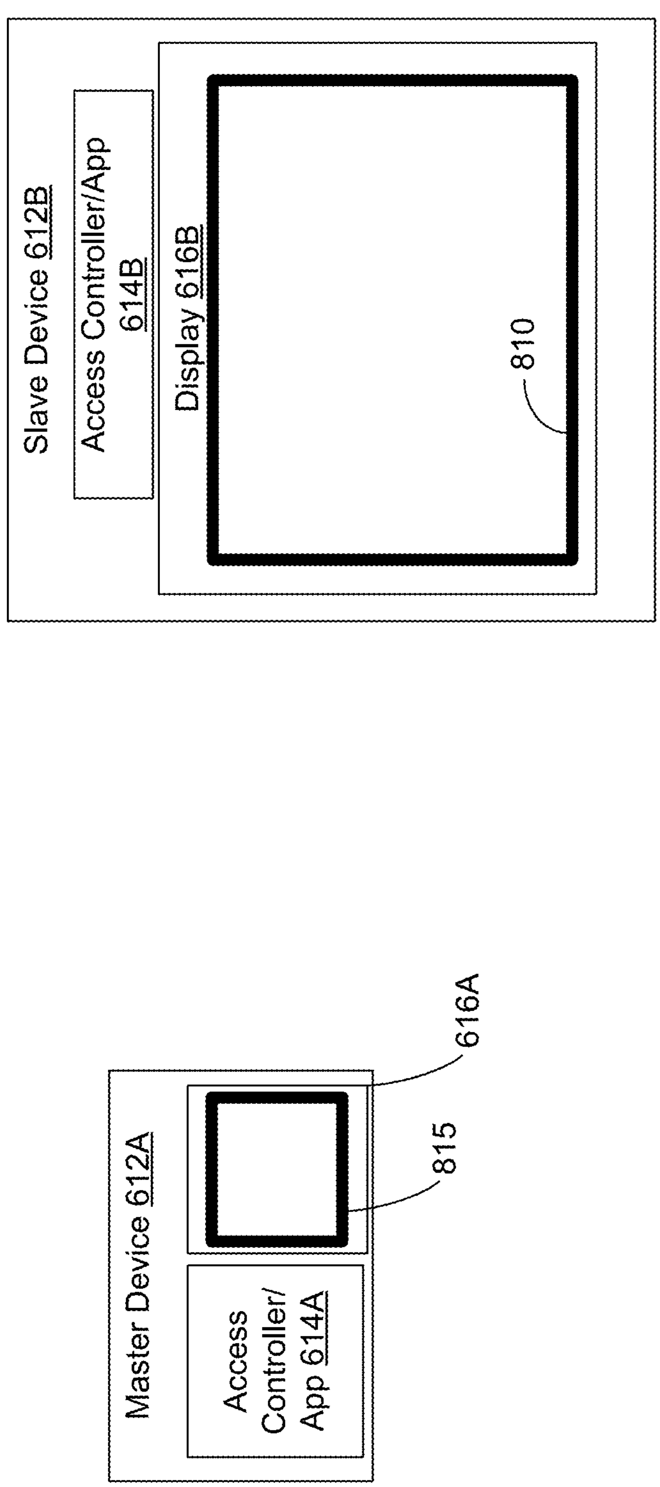

Slave Device 612B
Access Controller/App 614B
Display 616B
810
Master Device 612A
Access Controller/ App 614A
815
616A

FIG. 8B

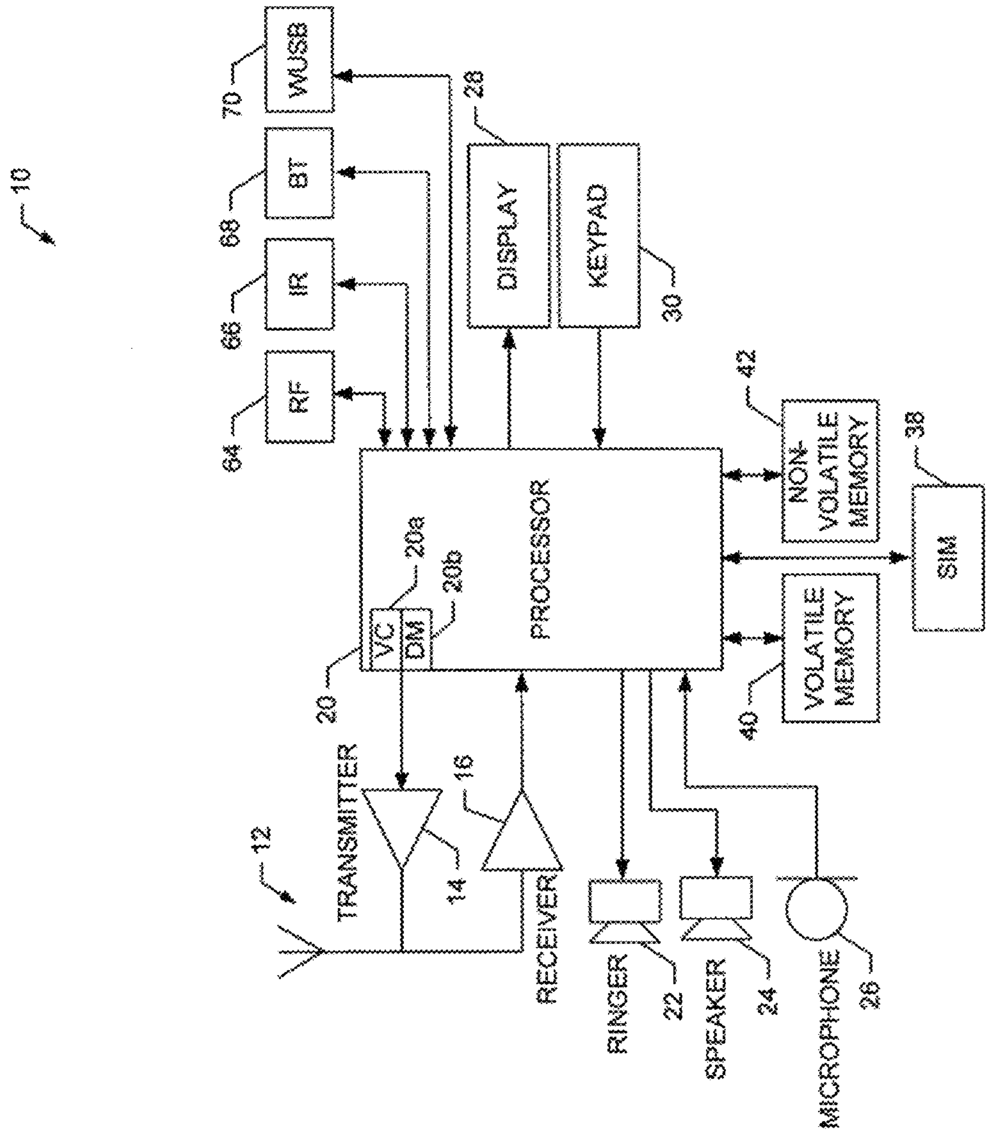

10
12
TRANSMITTER
14
16
RECEIVER
RINGER
22
SPEAKER
24
MICROPHONE
26
20
VC
DM
20a
20b
PROCESSOR
64
RF
66
IR
68
BT
70
WUSB
28
DISPLAY
KEYPAD
30
42
NON-VOLATILE MEMORY
38
SIM
40
VOLATILE MEMORY

FIG. 9

DEVICE SYNCHRONIZATION

FIELD

The subject matter described herein relates to wireless communications.

BACKGROUND

Master timing among devices can be derived from a master device's native clock. Slave device(s) may keep an estimate of the master device's native clock by adding a timing offset to the slave's native clock. This offset may be updated each time a packet is received from the master. In this way, master timing is not affected by time drifts at slave device(s).

SUMMARY

Methods and apparatus, including computer program products, are provided for device synchronization.

In one aspect there is provided a method. The method may include establishing, at a first wireless device, a clock to be shared with at least a second wireless device; and sending, by the first wireless device over a short-range wireless link, a command to at least the second wireless device, the command indicating an operation to be performed by at least the second wireless device at a time defined by the clock.

In some variations, one or more of the features disclosed herein including the following features can optionally be included in any feasible combination. The operation may include presentation of an image by a display at the second wireless device. The first wireless device may detect an image presented by a display at the second wireless device, the image being presented at the time indicated by the command. The first wireless device may select the second wireless device for communications, when the first wireless device detects the image presented by the display at the second wireless device. The first wireless device may forward, in response to the selecting, data for presentation at the second wireless device. The operation may include playing, at the time, audio content at the second wireless device. An audio delay may be determined between the first wireless device and the second wireless device by at least determining a difference between the time when the audio is played by the second wireless device and another time when the audio is received by the first wireless device. The clock may include a master clock. At the first wireless device, the master clock may represent a native Bluetooth clock. At the second wireless device, the master clock may represent an estimate of the master clock determined based on an offset added to a clock local to the second wireless device. The time defined by the clock may represent the time being synchronized to the clock.

The above-noted aspects and features may be implemented in systems, apparatus, methods, and/or articles depending on the desired configuration. The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. **1** depicts an example of a system implementing device synchronization, in accordance with some exemplary embodiments;

FIG. **2** depicts an example of a clock;

FIG. **3** depicts an example of a process for reading clock offsets;

FIG. **4** depicts an example of a system configured to measure acoustic delay, in accordance with some exemplary embodiments;

FIG. **5** depicts an example of a process for device synchronization, in accordance with some exemplary embodiments;

FIG. **6** depicts another example of a system implementing device synchronization and an operation enabling so-called "easy access" in accordance with some exemplary embodiments;

FIG. **7** depicts an example of a process for easy access, in accordance with some exemplary embodiments;

FIG. **8**A depicts an example of an image presented at a certain time based on the device synchronization, in accordance with some exemplary embodiments;

FIG. **8**B depicts an example of an indication presented at devices to indicate compatibility and/or the success of the easy, in accordance with some exemplary embodiments; and

FIG. **9** depicts an example of a wireless user equipment, in accordance with some exemplary embodiments.

Like labels are used to refer to same or similar items in the drawings.

DETAILED DESCRIPTION

Performing synchronized actions in the two or more wireless devices in a network including a local area network may present challenges. For example, when a device commands a peer device to perform an operation, such as emitting audio signal, capture sound, capture an image, and the like, there can be relatively long and/or relatively unpredictable latencies associated with processing at the devices (for example, software-related stack delays, radio-related stack delays, and the like). This unpredictability may make it difficult to synchronize operations among the devices.

In some example embodiments, the subject matter described herein may relate to defining a common clock for a plurality of devices. This common clock structure may provide a time base to synchronize operations among the devices. For example, devices having short-range radio transceivers, such as Bluetooth, Bluetooth Low Energy, and/or any other short-range radio access technology, may be synchronized with a master network clock (or time), so that a command issued by a first wireless device can be executed by other devices at a certain time (or clock cycle) defined by the network clock.

In some example embodiments, the subject matter disclosed herein may also relate to enabling so-called "easy access" among devices to allow the devices to share content and/or resources.

FIG. **1** depicts an example of a system **100** including wireless devices **112**A-C, in accordance with some example embodiments. In the example of FIG. **1**, wireless device **112**A is referred to as a master, and devices **112**B-C are referred to as slaves. The term "master" may be used to merely refer to a device that provides a synchronization reference to slaves. Depending on the device initiating a connection or a role switch request, other devices **112**B-C may serve as a master, and device **112**A may serve as a slave.

In some example embodiments, master wireless device **112**A may couple to slave wireless devices **112**B-C via short-range radio links, such as Bluetooth, Bluetooth Low Energy, Wi-Fi, or the like. For example, wireless device **112**A may comprise user equipment, such as a smartphone, coupling via short-range radio transceivers to wireless devices **112**B-C to form a local area network, such as a Bluetooth piconet, although other types of networks may be formed as well.

In some example embodiments, master wireless device **112**A and one or more slave wireless devices **112**B-C may synchronize under a master network clock (also referred to herein as network time or, in the case of a piconet, piconet time). When synchronized, master wireless device **112**A may issue a certain command requesting an operation to be performed at a certain time by one or more of slave wireless devices **112**B-C. For example, master wireless device **112**A may send a command to a slave wireless device **112**B to perform a first operation, such as play an audio tone, display an image, and/or perform any other operation, at a certain, future time value. This time value may be relative to the master network clock. When that first time value occurs, slave device **112**B may then execute the operation. In addition or alternatively, master wireless device **112**A may instruct slave wireless device **112**C to perform a second operation at another time (for example, at the time value or any other time as well). As such, the operations performed by devices **112**A-C are predictable with respect to the master network clock shared by the devices **112**A-C.

Although the previous example describes a master sending a command, a slave may send a command to a master or another slave as well.

FIG. **2** depicts an example of a clock. When devices **112**A-C include Bluetooth radio access technology, the devices **112**A-C may also have a native clock derived from a free running system clock. For synchronization with other devices, timing offsets (also referred to as clock offsets or, more simply, offsets) can added to a device's native clock to provide a master network clock (or piconetwork time in the case of a piconet). A device can derive the master network clock from a master device's native clock. For example, a slave device may maintain an estimate of the master device's native Bluetooth clock (which can thus serve as a master network clock) by adding a timing offset to the slave's native clock. This offset may be updated each time a packet is received from the master. In this way, the master clock at a slave device may be relative to a master and thus not substantially affected by time drifts in the slave device.

In some example embodiments, devices **112**A-C may be configured to read a piconet clock in order to determine a master clock using a host controller interface (HCI) command, such as HCI_Read_Clock. When that is the case, the slave device may provide parameters to HCI_Read_Clock command, which would return a piconet clock value. Any connection handle having a connection to a wanted master can be used. The read piconet value may be used directly, although the clock offset and native clock is the value needed that can be obtained as noted.

FIG. **3** depicts an example of a process **300** in which piconet clock are read, in accordance with some example embodiments.

In the example of FIG. **3**, one of the devices acting as a master, such a wireless device **112**A, may send, at **305** to a link manager (LM) at device **112**A. The link manager may acknowledge with a command status at **310** and may send at **315** a link management protocol clock offset request (LMP_clockoffset_req) to a slave device **112**B (or link manger therein). The slave device **112**B may respond at **320** to master wireless device **112**A with a clock offset value being used by the slave wireless device **112**B. The link manager at master wireless device **112**A may provide at **325** the clock offset value to a host at master wireless device **112**A. In this way, the devices **112**A-C can each read or otherwise obtain the clock offsets being used at each of the devices **112**A-C. When master wireless device **112**A knows the clock offsets being used by slave wireless devices **112**B-C, master wireless device **112**A may send commands to slave wireless devices **112**B and/or C to perform certain commands at certain times. As devices **112**A-C are in synchronization under a master network clock, master wireless device **112**A can predict when an operation will occur at slave wireless device **112**B-C.

Although FIG. **3** describes reading clock offsets from other devices, devices can also read clock values from other devices using for example a host control interface command, such as HCI_Read_Clock. When this is the case, the HCI_Read_Clock command may be used to read an estimate of the value of the piconet Bluetooth clock at a device from a Basic Rate/Enhanced Data Rate (BR/EDR) controller, which is the estimate of the master (piconet) clock.

In some example embodiments, master device **112**A may read its own clock (which serves as the master network clock or piconet time), and slave devices **112**B-C may read the master network clock/piconet time (which is the same or similar to the master device's clock adjusted by the clock offset for each slave device). This master network clock/piconet time value is then used to synchronize the operations performed by devices **112**A-C.

In some example embodiments, devices **112**A-C may read clock information (for example, master network time and the like) without host or application level connections by, for example, while reading the service discovery protocol (SDP) record of a discoverable device. The clock value (when something happens) can be communicated over some other network than the network, which is using the clock values as a network clock and this clock value may be used to synchronize some other network actions, such as a beaconing/scanning activity in the network.

The time that is used to synchronize actions may represent a so-called "absolute" time that is the same in both ends. If device A gives a time as "**12345**" for a certain event to occur at device B, device B may use this time directly and compare the time "**12345**" to device B's own clock estimate. To illustrate further, device B may receive time "**12345**" from device A, and then device B may read its own clock estimate of "**12340**." In this example, device B knows that in 5 clock cycles, an action will be performed as directed by device A.

Referring again to FIGS. **1** and **2**, master device **112**A may instruct slave device **112**B to perform an operation at, for example, clock (CLK) **1** and instruct slave device **112**C to perform the same or different operation at clock (CLK) **1** or any other clock time, in accordance with some example embodiments. Moreover, the operation and/or the clock time may be predefined. For example, the command sent by the master device over the short-range link may explicitly include the requested operation and/or the time, or the command may instead implicitly indicate a predetermined operation and/or a predetermined time (for example, a single bit command can be used to indicate a predetermined operation at a predetermined time).

In some example embodiments, the synchronized operation(s) may comprise audio playback to allow determination of acoustic delay between devices. For example, master device **112**A may want to know acoustic delay associated with the distance between devices **112**A-B to compensate the audio for such delays and/or whatever reason.

FIG. **4** depicts an example system **400** including master device **112**A coupled via short-range link **199**B to slave device **112**B. The acoustic delay ($\Delta T = T2 - T1$) can be used to calculate distance between devices and the like. In the example of FIG. **4**, master device **112**A may request via link **199**B that slave device **112**B perform an operation at a certain time defined by the master clock, such as a certain clock time defined with respect to for example the master clock of FIG. **2**. The operation, in the example of FIG. **4**, may be emitting an audio tone at a certain piconet time, such as 0x00002A23, which is depicted as time T**1** at FIG. **4**. Because master device **112**A and slave device **112**B are synchronized to a common master clock, master device **112**A can determine the acoustic signal delay between devices **112**A-B by measuring when the acoustic signal is received at a speaker of device **112**A (labeled time, T**2**) and adjusting for other delays (for example, radio, software, and so forth) at master device **112**A. These other delays are taken into account at FIG. **4** at T**3**.

Rather than have the slaves emit audio that is then detected by the master, the master may emit an audio tone, which can then detected by the slaves to determine acoustic delay between devices.

Another way is that Slave device **112**B and Slave device **112**C report exact time T**1** to Master device **112**A, where the slaved devices' own microphone can be for example used to detect T**1** if there is for example some uncertainly when the audio exactly emitted compared to time request by master device **112**A. For example, audio may be emitted by a given device at a Bluetooth clock time value (for example, 0x00002A23), and slave **112**B measures with its own microphone when the sound is actually sent (for example, T**1**) and reports possible delays between wanted time and actual time T**1**.

In some example embodiments, the synchronized operation may comprise having one or more of slave devices **112**B-C record a position, such as a geolocation, at a defined master network clock/piconet time and then report those values back to master device **112**A. When devices have motion sensing, the displacement of the device may also be monitored so that a device can update position information only when the devices has been moved sufficiently as triggered by motion sensing.

FIG. **5** depicts an example of a process for device synchronization, in accordance with some example embodiments. The description of FIG. **5** also refers to FIGS. **1** and **2**.

At **510**, master wireless device **112**A may establish a master clock to be shared among slave devices **112**B-C, in accordance with some example embodiments. For example, master wireless device **112**A and slave device **112**B-C may establish a network clock (or piconet time) among devices coupled by short-range links, such as Bluetooth and the like. The master device **112**A may use its own native clock as the master clock, while slaves **112**B-C may, as noted above, add offsets to the native device's clock to obtain the slave's version of the master clock.

At **515**, master wireless device **112**A may send over the short-range wireless link, such as Bluetooth and the like, a command to at least one of the slave wireless devices **112**B-C. This command may indicating an operation, such as play audio, display an image, and the like, to be performed by at least at least one of the slave wireless devices **112**B-C at a certain time in the future. Moreover, this certain time may be defined based on the master clock established at **510**. For example, the certain time may be defined as specific clock time, such as clock within a Bluetooth master clock pattern as described above with respect to FIG. **2**.

At **520**, at least one of the slave wireless devices **112**B-C performs the command, in accordance with some example embodiments. For example, the command may instruct slave device **112**B to play an audio tone, present an image on a display, and the like, at a certain time, such as clock (CLK) **12** as depicted at FIG. **2**. When the piconet clock at slave device **112**B indicates clock (CLK) **12**, slave device **112**B performs the operation. In some example embodiments, the slave device may send to master device **112**A an acknowledgement confirming receipt of the command at **515**. Additionally or alternatively, slave device may send to master device **112**A an acknowledgement confirming completion of the operation at **520**.

In some example embodiments, synchronized operation may, as noted, comprise an image being presented at a certain time on the displays of one or more slave devices. The master device's camera or other image sensor may capture, at the certain time, the image being displayed by the slave(s). In some example embodiments, the image display and capture process may be used to indicate compatibility with a certain feature. For example, the feature may be a so-called "easy access" media or resource sharing capability at the master device and the slave device. The following description relates to this "easy access" media or resource sharing capability.

FIG. **6** depicts an example of a system **600** including devices **612**A-C, each of which includes a short-range transceiver **617**A-C, in accordance with some example embodiments. The short-range transceivers may be implemented as a Bluetooth radio, a Bluetooth Low Energy, a Wi-Fi radio, and/or any other short-range radio access technology.

Device **612**A (labeled master device) may be implemented as a smartphone, a user equipment, and/or any other device. Device **612**A may also include a user interface including a display **616**A and an access controller, such as application **614**A. In some example embodiments, application **614**A is an easy access application configured to enable device **612**A to provide or share media and/or other resources with other devices having a compatible easy access application. In the example of FIG. **6**, device **612**B (labeled slave device) includes an access controller, such as application **614**B, but device **612**C does not. Devices **612**B-C may be implemented as a television, a music player, a media device, a tablet, a user equipment, a smartphone, and/or any other device. Devices **612**B-C may also include user interfaces, such as displays **616**B-C.

The following provides an example use case for the easy access application disclosed herein. For example, Bob may be using wireless device **612**A, and may want to show and share content, such as video, images, and the like, on device **612**A with Jane who is using device **612**B. Rather than use display **616**A on device **612**A, Bob would rather use a larger display **616**B available at Jane's device **612**B. In some example embodiments, Jane's device **612**B is a television including an access controller/application **614**B, although Jane's device may be another type of device as well. The applications **614**A-B may provide easy access connectivity and sharing capabilities among devices **612**A-B (which include access controllers/applications **614**A-B).

Bob's wireless device **612**A may, in some example embodiments, discover and/or detect one or more other devices, such as devices **612**B-C. For example, Bob's wireless device **612**A may include a short-range radio transceiver and discover and/or detect other short-range radio transceivers at devices **612**B-C. Next, Bob's wireless device **612**A may synchronize with the discovered device(s), such as devices **612**B-C. In some example embodiments, the synchronization may be in accordance with process **500**, so a network clock or piconet time is established, although other forms of synchronization may be established as well.

When synchronization is established, Bob's wireless device **612**A may, in some example embodiments, send via the short-range link a command requesting that Jane's wireless device **612**B present on display **616**B an identifiable pattern at a certain time in accordance with the synchronization provided by, for example, network clock or piconet time. However, device **612**C may not present the identifiable pattern at a certain time because device **612**C does not include the easy access capability provided by, for example, an access controller/application as in devices **612**A-B.

Because devices **612**A-B are in synchronization and include access controllers/applications **614**A-B, Bob's wireless device **612**A may detect an identifiable pattern, such as an image. For example, Bob's wireless device **612**A may include a camera (or other type of image detector) to detect, at the certain time, the identifiable image pattern presented at display **616**B of Jane's device **612**B. Although this pattern may be detectable by humans, this pattern may, in some implementations, not be detectable by a user (for example, the pattern presented as an image at display **616**B may be presented in one or two frames per second so, although detectable by a machine, not detectable by a human due to human perceptual limitations with respect to frame rate).

When the pattern is detected by Bob's wireless device **612**A, wireless device **612**A recognizes that wireless devices **612**A has an access application/controller **614**A and the corresponding easy access functionality to facilitate sharing and the like. The devices **612**A-B may then establish (or complete the establishment of) connections via short-range links including application (and/or host)-level connections between applications **614**A and **614**B. In some example embodiments, an indication may be provided to Jane and/or Bob to indicate easy access compatibility as well. For example, devices **612**A and/or device **612**B may indicate compatibility by presenting an image (for example, box encircling the display **616**A or **616**B), a sound, and/or the like to indicate to Bob the easy access functionality provided by access controller/applications **614**A and **614**B. Devices **612**A-B may then proceed to share resources by for example allowing Bob's device **612**A to stream a video to Jane's display **616**B via the short-range link. While Bob's wireless device **612**A is within range of Jane's wireless device **612**B, Bob's wireless device **612**A can forward media to Jane's wireless device **612**B and display **616**B. From Bob's perspective, Bob shared media with Jane by launching an application **614**A to share the media, pointing the wireless device **612**A towards display **616**B at Jane's wireless device **612**B, viewing an indication of success/compatibility at display **616**B (for example, a box encircling display **616**B or other indication), and finally coupling to Jane's wireless device **612**B to view media streamed from Bob's wireless device **612**A to display **616**B at Jane's wireless device **612**B.

FIG. **7** depicts an example process for facilitating access between devices, in accordance with some example embodiments. The description of process **700** also refers to FIG. **6**.

At **710**, a device may discover one or more other devices, in accordance with some example embodiments. For example, device **612**A may discover one or more other devices **612**B-C by scanning for other devices having local connectivity bearers, such as short-range bearers including Bluetooth, Bluetooth Low Energy, Wi-Fi, and the like. This discovery may be stored and be performed as, for example, a background task at device **612**A. In the case of Bluetooth, the discovery may be performed in accordance with a Bluetooth page-and-response protocol. When device **612**A detects a device, such as device **612**B or **612**C, device **612**A may proceed to establish connectivity between device **612**A and the detected device(s) via short-range links. This connectivity may include short-range radio bearers, application level connectivity, and/or the like.

At **715**, synchronization may, in some example embodiments, occur between devices **612**A-**612**B to establish a common, network clock (for example, piconet in the case of a Bluetooth piconet). The synchronization may be performed in accordance with process **500** described above, although other synchronization processes may be used as well. In addition to reading master clock and offset information as noted above, synchronization among devices may be derived in other ways, such as via beacons or other messages found in Bluetooth, Bluetooth Low Energy, Wi-Fi, and the like.

At **720**, the synchronization may, in some example embodiments, enable device **612**A to send a command to device **612**B and/or **612**C at a predetermined time. For example, device **612**A may send to devices **612**B and/or **612**C a command to request display of a predetermined image at a certain time. This time may be relative to the common network clock established at **715**. Device **612**B being synchronized to device **612**A and having application **614**B, displays the predetermined image at a predetermined time, such as clock time **4** (for example, CLK **4** at FIG. **2**) to enable detection by a camera or image detector at device **612**A. FIG. **8**A depicts an example of the predetermined image presented at clock time **4**. Referring again to FIG. **7**, device **612**B may detect the command and present the image but device **612**C (which does not include an easy access controller/application) does not display the predetermined image.

As device **612**A is synchronized with device **612**B, device **612**A may have its camera (or image detector) generally pointed in the direction of display **616**B and, consequently, may, in some example embodiments, detect, at **725**, the predetermined image (for example, pattern) at display **616**B at a predetermined time. Referring to the previous example, device **612**A may detect the image depicted at FIG. **8**A at clock time **4**. For example, device **612**A's camera (or image detector) may capture an image (for example, pixels) for the predetermined image presented at display **616**B, and this capture may be performed during the predetermined time (or just before and after). In any case, a processor at the device **112**A may then process the captured image (or pixels) to detect whether the predetermined image was in the image. A template may scan the captured image for possible matches, although other image detection techniques may be used as well. At **725**, device **612**A may, in some example embodiments, wait for a trigger event indicating that easy access should proceed. For example, a selection at a user interface at device **612**A may initiate the easy access command and the subsequent image capture of the image presented at display **616**B. In addition or alternatively, an acceleration sensor or a camera button may initiate the easy access command and the subsequent image capture of the image presented at display **616**B. Device **612**A may also include sensors and/or inertial sensors to detect whether the camera is in a position in which the camera at device **612**A can capture an image presented at display **616**B.

In some example embodiments, the displayed predetermined image **805** at device **612**B may be selected to enhance detection by other devices. For example, the predetermined image **805** may include areas of high contrast areas that are easier to detect. Moreover, the predetermined image **805** may have varying size to facilitate capture at different distances, angles, and the like. In some example embodiments, device **612**A may estimate the distance to device **612**B (for example, using a received signal strength indicator and the like) and command device **612**B to present a certain sized image **805** based on the determined distance.

When device **612**A detects the predetermined image **805** at the predetermined time defined by the network clock or synchronization established at **715**, device **612**A may, in some example embodiments, generate an indication to be presented at device **612**A and/or **612**B. This indication may alert a user that the devices **612**A-B are compatible with respect to the "easy" access application **614**A-B, and that the easy access has been successful. Referring to FIG. **8**B, the indication at device **612**A may be a visual indication **815** at the user interface or display **616**A of device **612**A, and/or a visual indication **810** at the user interface or display **616**B of device **612**B. The indications may take other forms including audible, haptic, and so forth.

In some example embodiments, the device taking the image, such as device **612**A, may provide the camera frame rate as a parameter to the display at slave device **612**B, and/or the display at slave device **612**B may provide the screen refresh rate and the offset to the piconet clock as a parameter to the device **612**A (for example, 15 frames per second, 24 microseconds, and the like). By doing this, the devices **612**A and **612**B may be able to better align the time instance(s), when the image is displayed on screen to the time instance(s) when the device **612**A is taking the picture(s) of the display **616**B. This may be implemented by starting the sharing application **614**A; the sharing application **614**A initiating a scan for Bluetooth devices; and the sharing application sending a command to the device(s) **612**B and the like to show pairing data on their displays. The device **612**A including sharing application **614**A may then start taking pictures of the display **616**B, record a time difference between when device **612**A detects the display **616**B to be changing/blinking/refreshing/presenting an image and the Bluetooth clock for two consecutive screen changes. As such, there is information on the device **612**A when it can detect a certain operation on display **616**B (for example, display blinking and the like) and compare that with the Bluetooth network clock instances. By informing this to the display **616**B/device **612**B, the two devices **612**A and **612**B may time the operation, such as code blinking and the like, to be visible for a minimal time on the screen (which may address the issue of different camera image capturing and display refresh rates).

At **735**, device **612**A may forward media to device **612**B, so that the media can be shared at device **612**B. For example, media, such as an image, video, and the like, at device **612**A may be streamed to the display **612**B to allow sharing of the content and, in this example, display **616**B. In some example embodiments, access controller/applications **614**A-B may also provide configuration information to facilitate the sharing between the devices **612**A-B.

In some example embodiments, device **612**A may be implemented as a smartphone or other user equipment having a plurality of radio access technologies including short-range radio transceivers, such as Bluetooth, Bluetooth Low Energy, Wi-Fi, and/or any other radio access technology. The device **612**A may attempt discovery of one or more other devices, such as device **112**B. For example, device **612**B may be implemented as a television including application **614**B providing so-called "easy access" via for example process **700** to other devices. Devices **612**A-B may also become aware of the easy access compatibility provided by access controller/application **614**A-B based on an SDP record (in the case of Bluetooth and the like). This SDP record may advertise the easy access compatibility. In the case of Wi-Fi, a public action frame may also be used to indicate the easy access compatibility.

When multiple devices are proximate to device **612**A, device **612**A may send a command that each device present a locally unique pattern, in accordance with some example embodiments. Device **112**A may detect the locally unique pattern and thus a specific device from among the devices (for example, by a matching address (such as Bluetooth, Wi-Fi, media access control address) with the specific patterns delivered to each device). This enables device **612**A to connect the media (for example, a video/image at device **612**B) to a radio level address of device **612**B.

In some example embodiments, because device **612**A knows when and what exact patterns are used by a given device, such as device **612**B, device **612**A is able to limit the capture and processing of image frames to detect the pattern at **725** to specific frames. This processing reduction may also facilitate reduced delays and real (or near) time processing at **725**.

In some example embodiments, the relative display sizes (for example, size of display **616**B) of a device can be estimated based on the size of the image captured and detected at **725**, although a device may also provide device description information including display size during the initial discovery or a user may select/provide this information as well.

In some example embodiments, display **616**A may present one or more images corresponding to content being presented on devices **612**B and the like. When one of those images is selected, device **612**A pairs with the selected device **612**B, such as a television and/or any other device (using, for example, a push button and/or out-of-band type of approach in both Bluetooth and WiFi/WLAN cases). When this is the case, device **612**A may send a command to device **612**B to cease presenting the pattern as the device has been detected.

In some example embodiments, device **612**A may scan an area to create a virtual map of devices, which can be presented on display **616**A at device **612**A. This virtual map may show the order in which the different device where detected. The user of device **612**A may use this virtual map to select a device (for example, connect to a television and the like) to connect to send different images to different device displays by for example swiping different images, video, and/or other media to each of the virtual screens on his device.

FIG. **9** illustrates a block diagram of an apparatus **10**, which can be configured as a wireless user equipment, in accordance with some example embodiments. For example, apparatus **10** may be implemented at devices **112**A-C and **612**A-C. In the case of the device being a television for example, the television may include one or more aspects of apparatus **10**. For example, a television may include a radio transceiver, such as a Bluetooth, Bluetooth Low Energy, or Wi-Fi radio transceiver, processor, and the like.

Apparatus **10** may be implemented as a smart phone, mobile station, a mobile unit, a subscriber station, a wireless terminal, a tablet, a wireless plug-in accessory, a television, or any other device with a short-range transceiver, such as Bluetooth, Bluetooth Low Energy, Wi-Fi, and the like.

The apparatus **10** may include at least one antenna **12** in communication with a transmitter **14** and a receiver **16**. Alternatively transmit and receive antennas may be separate.

The apparatus **10** may also include a processor **20** configured to provide signals to and receive signals from the transmitter and receiver, respectively, and to control the functioning of the apparatus. Processor **20** may be configured to control the functioning of the transmitter and receiver by effecting control signaling via electrical leads to the transmitter and receiver. Likewise, processor **20** may be configured to control other elements of apparatus **10** by effecting control signaling via electrical leads connecting processor **20** to the other elements, such as a display or a memory. The processor **20** may, for example, be embodied in a variety of ways including circuitry, at least one processing core, one or more microprocessors with accompanying digital signal processor(s), one or more processor(s) without an accompanying digital signal processor, one or more coprocessors, one or more multi-core processors, one or more controllers, processing circuitry, one or more computers, various other processing elements including integrated circuits (for example, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), and/or the like), or some combination thereof. Accordingly, although illustrated in FIG. **9** as a single processor, in some example embodiments the processor **20** may comprise a plurality of processors or processing cores.

Signals sent and received by the processor **20** may include signaling information in accordance with an air interface standard of an applicable cellular system, and/or any number of different wireline or wireless networking techniques, comprising Wi-Fi, wireless local access network (WLAN) techniques, such as Institute of Electrical and Electronics Engineers (IEEE) 802.11, 802.16, and/or the like. In addition, these signals may include speech data, user generated data, user requested data, and/or the like.

The apparatus **10** may be capable of operating with one or more air interface standards, communication protocols, modulation types, access types, and/or the like. For example, the apparatus **10** and/or a cellular modem therein may be capable of operating in accordance with various first generation (1G) communication protocols, second generation (2G or 2.5G) communication protocols, third-generation (3G) communication protocols, fourth-generation (4G) communication protocols, Internet Protocol Multimedia Subsystem (IMS) communication protocols (for example, session initiation protocol (SIP) and/or the like. For example, the apparatus **10** may be capable of operating in accordance with 2G wireless communication protocols IS-136, Time Division Multiple Access TDMA, Global System for Mobile communications, GSM, IS-95, Code Division Multiple Access, CDMA, and/or the like. In addition, for example, the apparatus **10** may be capable of operating in accordance with 2.5G wireless communication protocols General Packet Radio Service (GPRS), Enhanced Data GSM Environment (EDGE), and/or the like. Further, for example, the apparatus **10** may be capable of operating in accordance with 3G wireless communication protocols, such as Universal Mobile Telecommunications System (UMTS), Code Division Multiple Access 2000 (CDMA2000), Wideband Code Division Multiple Access (WCDMA), Time Division-Synchronous Code Division Multiple Access (TD-SCDMA), and/or the like. The apparatus **10** may be additionally capable of operating in accordance with 3.9G wireless communication protocols, such as Long Term Evolution (LTE), Evolved Universal Terrestrial Radio Access Network (E-UTRAN), and/or the like. Additionally, for example, the apparatus **10** may be capable of operating in accordance with 4G wireless communication protocols, such as LTE Advanced and/or the like as well as similar wireless communication protocols that may be subsequently developed.

It is understood that the processor **20** may include circuitry for implementing audio/video and logic functions of apparatus **10**. For example, the processor **20** may comprise a digital signal processor device, a microprocessor device, an analog-to-digital converter, a digital-to-analog converter, and/or the like. Control and signal processing functions of the apparatus **10** may be allocated between these devices according to their respective capabilities. The processor **20** may additionally comprise an internal voice coder (VC) **20***a*, an internal data modem (DM) **20***b*, and/or the like. Further, the processor **20** may include functionality to operate one or more software programs, which may be stored in memory. In general, processor **20** and stored software instructions may be configured to cause apparatus **10** to perform actions. For example, processor **20** may be capable of operating a connectivity program, such as a web browser. The connectivity program may allow the apparatus **10** to transmit and receive web content, such as location-based content, according to a protocol, such as wireless application protocol, WAP, hypertext transfer protocol, HTTP, and/or the like.

Apparatus **10** may also comprise a user interface including, for example, an earphone or speaker **24**, a ringer **22**, a microphone **26**, a display **28**, a user input interface, and/or the like, which may be operationally coupled to the processor **20**. The display **28** may, as noted above, include a touch sensitive display, where a user may touch and/or gesture to make selections, enter values, and/or the like. The processor **20** may also include user interface circuitry configured to control at least some functions of one or more elements of the user interface, such as the speaker **24**, the ringer **22**, the microphone **26**, the display **28**, and/or the like. The processor **20** and/or user interface circuitry comprising the processor **20** may be configured to control one or more functions of one or more elements of the user interface through computer program instructions, for example, software and/or firmware, stored on a memory accessible to the processor **20**, for example, volatile memory **40**, non-volatile memory **42**, and/or the like. The apparatus **10** may include a battery for powering various circuits related to the mobile terminal, for example, a circuit to provide mechanical vibration as a detectable output. The user input interface may comprise devices allowing the apparatus **20** to receive data, such as a keypad **30** (which can be a virtual keyboard presented on display **28** or an externally coupled keyboard) and/or other input devices.

As shown in FIG. **9**, apparatus **10** may also include one or more mechanisms for sharing and/or obtaining data. For example, the apparatus **10** may include a short-range radio frequency (RF) transceiver and/or interrogator **64**, so data may be shared with and/or obtained from electronic devices in accordance with RF techniques. The apparatus **10** may include other short-range transceivers, such as an infrared (IR) transceiver **66**, a Bluetooth (BT) transceiver **68** operating using Bluetooth wireless technology, a wireless universal serial bus (WUSB) transceiver **70**, and/or the like. The Bluetooth transceiver **68** may be capable of operating according to Bluetooth Low Energy technology. In this regard, the apparatus **10** and, in particular, the short-range transceiver may be capable of transmitting data to and/or receiving data from electronic devices within a proximity of the apparatus, such as within 10 meters, for example. The apparatus **10** including the Wi-Fi or wireless local area networking modem may also be capable of transmitting and/or receiving data from electronic devices according to various wireless networking techniques, including 6LoWpan, Wi-Fi, Wi-Fi low power, WLAN techniques such as IEEE 802.11 techniques, IEEE 802.15 techniques, IEEE 802.16 techniques, and/or the like.

The apparatus **10** may comprise memory, such as a subscriber identity module (SIM) **38**, a removable user identity module (R-UIM), an eUICC, an UICC, and/or the like, which may store information elements related to a mobile subscriber. In addition to the SIM, the apparatus **10** may include other removable and/or fixed memory. The apparatus **10** may include volatile memory **40** and/or non-volatile memory **42**. For example, volatile memory **40** may include Random Access Memory (RAM) including dynamic and/or static RAM, on-chip or off-chip cache memory, and/or the like. Non-volatile memory **42**, which may be embedded and/or removable, may include, for example, read-only memory, flash memory, magnetic storage devices, for example, hard disks, floppy disk drives, magnetic tape, optical disc drives and/or media, non-volatile random access memory (NVRAM), and/or the like. Like volatile memory **40**, non-volatile memory **42** may include a cache area for temporary storage of data. At least part of the volatile and/or non-volatile memory may be embedded in processor **20**. The memories may store one or more software programs, instructions, pieces of information, data, and/or the like which may be used by the apparatus for performing functions of the user equipment/mobile terminal. The memories may comprise an identifier, such as an international mobile equipment identification (IMEI) code, capable of uniquely identifying apparatus **10**. The functions may include one or more of the operations disclosed herein with respect to the user equipment and devices, such as the functions disclosed at process **500** and **700**. The memories may comprise an identifier, such as an international mobile equipment identification (IMEI) code, capable of uniquely identifying apparatus **10**. In the example embodiment, the processor **20** may be configured using computer code stored at memory **40** and/or **42** to enable processes **500**, **700**, and/or the like as disclosed herein.

Some of the embodiments disclosed herein may be implemented in software, hardware, application logic, or a combination of software, hardware, and application logic. The software, application logic, and/or hardware may reside on memory **40**, the control apparatus **20**, or electronic components, for example. In some example embodiment, the application logic, software or an instruction set is maintained on any one of various conventional computer-readable media. In the context of this document, a "computer-readable medium" may be any non-transitory media that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer or data processor circuitry, with examples depicted at FIG. **9**. A computer-readable medium may comprise a non-transitory computer-readable storage medium that may be any media that can contain or store the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer. In addition, some of the embodiments disclosed herein include computer programs configured to cause methods as disclosed herein, such as establishing a clock to be shared with at least a second wireless device, sending over a short-range communication link a command to at least the second wireless device, the command indicating an operation to be performed by at least the second wireless device at a time defined by the clock, and the like.

Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is enhanced synchronization between devices coupled via short-range links and/or enhanced coupling and sharing of resources among devices.

If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined. Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims. It is also noted herein that while the above describes example embodiments, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications that may be made without departing from the scope of the present invention as defined in the appended claims. Other embodiments may be within the scope of the following claims. The term "based on" includes "based on at least."

What is claimed:

1. A method comprising:

establishing, at a first wireless device, a clock to be shared with at least a second wireless device;

sending, by the first wireless device over a short-range communication link, a command to at least the second wireless device, the command indicating an operation to be performed by at least the second wireless device at a time defined by the clock, wherein the operation comprises presentation of an image by a display at the second wireless device; and

detecting, by the first wireless device, the image presented by the display at the second wireless device, the image being presented at the time indicated by the command.

2. The method of claim **1** further comprising:

selecting, by the first wireless device, the second wireless device for communications, when the first wireless device detects the image presented by the display at the second wireless device.

3. The method of claim **2** further comprising:

forwarding, by the first wireless device in response to the selecting, data for presentation at the second wireless device.

4. The method of claim **1**, wherein the operation comprises playing, at the time, audio content at the second wireless device.

5. The method of claim **4** further comprising:

determining an audio delay between the first wireless device and the second wireless device by at least determining a difference between the time when the audio is played by the second wireless device and another time when the audio is received by the first wireless device.

6. The method of claim **1**, wherein the clock comprises a master clock, and wherein at the first wireless device, the master clock represents a native Bluetooth clock, and at the second wireless device, the master clock represents an estimate of the master clock determined based on an offset added to a clock local to the second wireless device.

7. The method of claim **1**, wherein the time defined by the clock represents the time being synchronized to the clock.

8. An apparatus comprising:

at least one processor circuitry; and

at least one memory circuitry including computer program code, the at least one memory circuitry and the computer program code configured to, with the at least one processor circuitry, cause the apparatus to perform at least the following:

establish, at the apparatus, a clock to be shared with at least another wireless device;

send, by the apparatus over a short-range wireless link, a command to at least the other wireless device, the command indicating an operation to be performed by at least the other wireless device at a time defined by the clock, wherein the operation comprises presentation of an image by a display at the other wireless device; and

detect, by the apparatus, the image presented by the display at the other wireless device, the image being presented at the time indicated by the command.

9. The apparatus of claim **8**, wherein the apparatus is further configured to at least select the other wireless device for communications, when the apparatus detects the image presented by the display at the other wireless device.

10. The apparatus of claim **9**, wherein the apparatus is further configured to at least forward, in response to the select, data for presentation at the other wireless device.

11. The apparatus of claim **8**, wherein the operation comprises playing, at the time, audio content at the other wireless device.

12. The apparatus of claim **11**, wherein the apparatus is further configured to at least determine an audio delay between the apparatus and the other wireless device based on a determined difference between the time when the audio is played by the other wireless device and another time when the audio is received by the apparatus.

13. The apparatus of claim **8**, wherein the clock comprises a master clock, and wherein at the apparatus, the master clock represents a native Bluetooth clock, and at the other wireless device, the master clock represents an estimate of the master clock determined based on an offset added to a clock local to the other wireless device.

14. The apparatus of claim **8**, wherein the time defined by the clock represents the time being synchronized to the clock.

15. A non-transitory computer-readable storage medium including computer program code, which when executed by at least one processor circuitry causes operations comprising:

establishing, at a first wireless device, a clock to be shared with at least a second wireless device;

sending, by the first wireless device over a short-range wireless link, a command to at least the second wireless device, the command indicating an operation to be performed by at least the second wireless device at a time defined by the clock, wherein the operation comprises presentation of an image by a display at the second wireless device; and

detecting, by the first wireless device, the image presented by the display at the second wireless device, the image being presented at the time indicated by the command.

* * * * *